Open File 95-3

Geologic Map of the Glenwood Springs Quadrangle, Garfield County, Colorado

DESCRIPTION OF MAP UNITS

By
Robert M. Kirkham, Randall K. Streufert, and James A. Cappa

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey STATEMAP program of the National Geologic Mapping Act of 1992, Agreement No. 1434-94-A-1225.

Colorado Geological Survey
Division of Minerals and Geology
Department of Natural Resources
Denver, Colorado
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SURFICIAL DEPOSITS

Surficial deposits shown on the map are generally more than about 5-ft thick, but may be thinner locally. Residual deposits and some artificial fills were not mapped. Contacts between surficial units may be gradation, and mapped occasionally include deposits of another type. Divisions of the Pleistocene correspond to those of Richmond and Fullerton (1986). Age assignments for surficial deposits are based primarily upon the degree of erosional modification of original surface morphology, height above stream level, and degree of soil development. Many of the surficial deposits are calcareous and contain varying amounts of both primary and secondary calcium carbonate.

HUMAN-MADE DEPOSITS

af — **Artificial fill (latest Holocene)**—Fill and waste rock deposited by man during construction and mining projects. Composed mostly of silt, sand, and rock fragments, but may include construction materials. Remnant debris from the coke ovens west of the Glenwood Springs Municipal Airport is also mapped as artificial fill. Maximum thickness about 50 ft. Poorly compacted fill may be subject to settlement when loaded.

ALLUVIAL DEPOSITS—**Silt, sand, and gravel deposited in stream channels, flood plains, terraces, debris fans, and sheet-wash areas along the Colorado River, Roaring Fork River, and their tributaries.**

Qa — **Stream-channel, flood-plain, and low terrace deposits (Holocene and late Pleistocene)**—Includes modern alluvium and other deposits underlying the Colorado and Roaring Fork Rivers, adjacent flood-plain deposits, and low terrace alluvium that is up to about 15 ft above modern stream level. May locally include organic-rich deposits. May be interbedded with younger debris-flow deposits where the distal ends of fans extend into modern river channels. Mostly clast-supported, slightly bouldery, pebble and cobble gravel in a sand matrix occasionally interbedded and overlain by sandy silt and gravelly sand. May locally include lacustrine deposits within Glenwood Canyon which were deposited when the river was blocked by rockfalls or debris flows. Unit is poorly to moderately well sorted and poorly to well bedded. Clasts are subangular to round, and their varied lithology reflects the diverse types of bedrock within their provenance. Flood-plain and terrace deposits included in this unit correlate with deposits in terrace T8 of Piety (1981). Maximum thickness about 154 ft in Glenwood Canyon (Bowen, 1988). Low-lying areas within this mapped unit are subject to flooding. May be a source of aggregate.

Qdfy — **Younger debris-flow deposits (Holocene)**—Sediments deposited in active debris-flow areas. Dominantly poorly sorted, clast- and matrix-supported, pebble and cobble gravel in a sandy silt or silty sand matrix; frequently very bouldery, particularly near fan heads. Distal part of many fans is characterized by mudflow and sheet-wash deposits and tends to be finer grained. Distal ends may be interfingered with modern alluvium adjacent to active stream channels. Unit locally grades to talus in steep canyons. Clasts are mostly angular to subround sedimentary rock and basalt fragments up to about 6 ft in diameter. Original depositional character of the surface of the unit is preserved, except where disturbed by human activities. Maximum thickness possibly about 120 ft. Subject to episodic debris-flow activity following intense rainstorms, except on distal ends, where mudflow and sheet-wash processes control sediment deposition. Distal parts may be prone to hydrocompaction. Subject to piping where underlain by evaporitic bedrock. Numerous sinkholes related to piping failure have reportedly developed in younger debris-flow deposits south of and across the river from Funston. Surface depressions created by settlement, hydrocompaction, or piping frequently may have been backfilled with unclassified fill placed by man and covered with soil, creating potentially hazardous foundation conditions for structures located over them. May be corrosive if derived from evaporitic rocks. May be a source of aggregate where derived from Precambrian and lower Paleozoic rocks.

Qsw **Sheet-wash deposits (Holocene and late Pleistocene)**—Includes deposits derived from weathered bedrock and unconsolidated, surficial materials that are transported dominantly by sheet erosion and accumulate in very small intermittent stream valleys or in basin areas which may lack external drainage. Common on gentle to moderate slopes underlain by limestone, shales, basalt, red beds, and landslide deposits. Typically consists of pebbly, silty sand and sandy silt. Maximum thickness probably about 25 ft. Subject to sheet wash and occasionally prone to settlement when loaded. May be susceptible to hydrocompaction, settlement, and piping when derived from Maroon Formation or evaporitic rocks.

Qdfm **Intermediate debris-flow deposits (Holocene and late Pleistocene)**—Similar in texture and depositional environment to younger debris-flow deposits (Qdfy), but slightly older. Geomorphic character of original depositional surface commonly recognizable, but the surface is topographically about 20 to 40 ft above active debris-flow channels. Generally not susceptible to future debris-flow activity unless a major blockage develops in an adjacent, active, debris-flow channel or during unusually large debris-flow events. Hydrocompaction, piping, and settlement may occur where the deposits are fine-grained.

Qty **Younger terrace alluvium (late Pleistocene)**—Chiefly stream alluvium underlying terraces that range from about 19 to 56 ft above modern stream level. May be capped by a single, thin loess sheet. Stream alluvium is mostly poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel with a sand matrix. May include fine-grained overbank deposits. Clasts are mainly subround to round and are comprised of a variety of lithologies reflecting the diverse types of bedrock found in their drainage basins. Granitic clasts generally unweathered or only slightly weathered, even at shallow depths. At the rest area on I-70 in West Glenwood Springs, unit is overlain by a tufa deposit which includes an interbedded thin, 0.1 to 0.3-ft thick, layer of organic-rich clayey sandy silt and peat. A sample of the peat has been submitted to the USGS for carbon-14 dating. May in part be equivalent to intermediate terrace alluvium (Qtm). Unit includes deposits in terrace T7 in the Carbondale-Glenwood Springs area described by Piety (1981). May also correlate with terrace A of Bryant (1979) in the Aspen area and in part with younger terrace alluvium of Fairer and others (1993) in the Storm King Mountain quadrangle. Unit is probably in part equivalent to outwash of the Pinedale glaciation, which Richmond (1986) estimated to be about 12 to 35 ka. Maximum thickness may locally exceed 100 ft, but is much thinner in other areas. May be a source of aggregate.

Qtm **Intermediate terrace alluvium (late Pleistocene)**—Composed of stream alluvium underlying terraces about 58 to 95 ft above modern stream level. May be capped by a single, thin loess sheet. Consists mostly of poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel with a sand matrix. Fine-grained overbank deposits locally present. Clasts are chiefly subround to round and consist of various lithologies that reflect the types of bedrock found in their drainage basins. Granitic clasts generally only slightly weathered at shallow depths. May in part be equivalent to younger terrace alluvium (Qty). Includes deposits in terrace T6 of the Carbondale-Glenwood Springs area of Piety (1981). May correlate with terrace B deposits of Bryant (1979) in the Aspen area and in part with younger terrace alluvium of Fairer and others (1993) in the Storm King Mountain quadrangle. Unit is probably equivalent to outwash from the Pinedale glaciation, which Richmond (1986) suggests is 12 to 35 ka. Maximum thickness probably around 100 ft. May be a source of aggregate.

Qdfo **Old debris-flow deposits (late, middle, and early? Pleistocene)**—Occur as remnants of formerly extensive debris fans deposited by tributaries to both the Roaring Fork and Colorado Rivers. Deposits occur primarily on ridge lines and mesas along the valley walls of the rivers, but also in the upper reaches of a few debris-flow basins that are tributary to the rivers. Original geomorphic surfaces are locally preserved and may be mantled with loess, but at other locations the deposits are deeply eroded and now geomorphically resemble the valley-wall topography developed on bedrock. Elevation differences between original depositional surface and adjacent modern drainages range from 40 to 320 ft. Texturally similar to younger debris-flow deposits (Qdfy), but frequently are highly calcareous. Boulders in excess of 5-ft diameter often found in deposits derived from larger debris-flow tributaries which have basalt or red beds within their basins. Locally contain thin interbeds of tufa and tufa-cemented gravel near West Glenwood Springs.

Deposits along Four Mile Creek include many rounded cobbles of basalt and occational lenses of silty sandy well rounded gravel, suggesting the unit is in part stream alluvium or that deposits of stream alluvium existed in the provenance area.

Deposits west of the Glenwood Springs Municipal Airport apparently have been folded and tilted away from river. This locality underlies the northern boundary of a halite dome within the Eagle Valley Evaporite described by Mallory (1966, 1971). Apparent deformation may relate to diapirism due to expansion of evaporite sequence as it was unloaded by erosion, hydration of anhydrite to gypsum, or perhaps upwelling resulting from flowage of a thick section of evaporitic rocks originally present beneath Spring Valley into the Roaring Fork Valley as its lateral confining pressure was reduced as the river downcut into the evaporite sequence. Upper surface on older debris-flow deposit at Fourmile Creek dips abruptly away from river and also climbs in elevation downriver. Nearest the river the surface is 20 to 100 ft higher than where it adjoins the valley wall. Along its eastern outcrop the surface is about 100 ft higher at the northern end than at its southern terminus. Direction of apparent folding is opposite of probable slope of original depositional surface on this older debris-flow deposit derived from Fourmile Creek, suggesting elevation differences on the surface represent a minimum structural relief for the folding.

Thickness generally about 30 to 60 ft, but may locally exceed 160 ft. Where fine-grained, unit may be prone to hydrocompaction, piping, and settlement. Corrosive when derived from evaporitic bedrock. May be a source of aggregate.

Qto **Older terrace alluvium (middle Pleistocene)**—Includes deposits of stream alluvium exposed on the north side of the Colorado River near and west of Glenwood Springs and also along the river at the eastern edge of the quadrangle. May be overlain by older debris-flow deposits (Qdfo) or a prominent bed of tufa (Qtu). Upper surface of unit ranges from about 110 to 140 ft above modern stream level. May interfinger with older debris-flow deposits (Qdfo) in West Glenwood Springs. Unit is generally a clast-supported, cobble or pebble gravel in a sand matrix with occasional small boulders, but may range to a matrix-supported, gravelly sand or gravelly silt. Clasts are chiefly subround to round, with varied lithologies that reflect the heterogeneous nature of the provenance area. Granitic clasts moderately weathered at shallow depths. Locally may include thin, tufa-cemented gravel beds and also fine-grained overbank deposits. Unit is tentatively correlated with terrace T5 in the Carbondale-Glenwood Springs area of Piety (1981), with terrace C of Bryant (1979) in the Aspen-Woody Creek area, and with older terrace alluvium of Fairer and others (1993). Deposits are probably of Bull Lake age, which may be about 140–150 ka (Pierce and others, 1976; Pierce, 1979) or about 130–300 ka (Richmond, 1986). Exposed thickness about 50 ft; maximum thickness estimated at about 130 ft. May be a source of aggregate.

Qtt **Oldest terrace alluvium (middle Pleistocene)**—Consists of stream alluvium west of the Glenwood Springs Municipal Airport that, in part, is overlain by older debris flow deposits (Qdfo). Upper surface of unit ranges from about 220 to 360 ft above the adjacent Roaring Fork River. Unit is poorly to moderately well sorted, clast-supported, slightly bouldery, cobble and pebble gravel with a sand matrix. Locally includes thin lenses and beds of sandy silt and silty sand. Gravel clasts are commonly moderately to strongly weathered, even at considerable depth. Unit overlies the northern boundary of a halite dome within the Eagle Valley Evaporite (Mallory, 1966, 1971), and along with the overlying older debris flow deposits (Qdfo) appears to be deformed by salt tectonism. Folding has altered the relative elevation difference between the older terrace deposits and the Roaring Fork River, which complicates assignment of even a relative age to the deposit. Piety (1981) tentatively mapped the remnant as a terrace T3 deposit, which contains the Lava Creek B volcanic ash in sec. 4, T. 8 S., R. 88 W. about 8 mi south-southeast of the quadrangle. The Lava Creek B ash, formerly called the Pearlette type O ash, is generally considered to be 620 ka (Izett and Wilcox, 1982). Maximum observed thickness about 200 ft. May be a source of aggregate.

QTg **High-level gravel (early Pleistocene or Pliocene)**—Includes a single, very poorly exposed deposit of river gravel which caps a ridge on the south side of the Colorado River about 1,500 ft above river level near the north quarter corner of sec. 7, T. 6 S., R. 88 W. Deposit recognized based on presence of subrounded to rounded cobbles and pebbles of quartzite, granite, and pegmatite in float observed on ground surface. Textural characteristics not observed. Probably deposited by ancestral Colorado River. Thickness unknown. May be a source of aggregate.

COLLUVIAL DEPOSITS—**Silt, sand, gravel, and clay on valley sides, valley floors, and hill slopes that were mobilized, transported, and deposited primarily by gravity, but frequently assisted by sheet erosion, freeze-thaw action, and water-saturated conditions that affect pore pressure.**

Qc **Colluvium (Holocene and late Pleistocene)**—Mostly clast-supported, pebble to boulder gravel in a sandy silt matrix that was derived from weathered bedrock and transported down gradient primarily by gravity, but aided by sheet erosion. Deposits usually coarser grained in upper reaches and finer grained in distal areas. Deposits derived from easily eroded formations tend to be finer grained and matrix supported. Clasts typically are angular to subangular. Commonly unsorted or poorly sorted with weak or no stratification. Clast lithology variable and dependent upon types of rocks occurring with the provenance area. Locally includes talus, landslide deposits, sheet-wash deposits, and debris-flow deposits that are too small or too indistinct on aerial photography to be mapped separately. Maximum thickness probably about 50 ft. Large areas on south and southeast side of Lookout Mountain that are mapped as Maroon Formation or basalt may be mantled by a thin veneer of colluvium. Areas mapped as colluvium are typically susceptible to active deposition and are frequently subject to sheet wash, rockfall, small debris flows, and minor landsliding. Fine-grained colluvium locally prone to hydrocompaction, piping, and settlement, particularly when derived from Maroon Formation or evaporitic rocks.

Qt **Talus (Holocene and late Pleistocene)**—Angular, cobbly and bouldery rubble on steep slopes that is derived from bedrock outcrops and is transported down slope principally by gravity as rockfalls, rockslides, rock avalanches, and rock topples. Locally may be aided by water and freeze-thaw processes. Generally derived from well indurated Precambrian and lower Paleozoic rocks or basalt. Locally lacks matrix material. May include alluvium and colluvium (Qac), particularly on narrow valley floors where talus is mapped on both sides of the valley floor. Areas covered with triangle pattern in No Name Creek indicate two very large deposits of talus that may have resulted from rapid rotational rockslides or large rock topples perhaps related to oversteepening of slopes due to glaciation or stream erosion. Maximum thickness estimated at about 80 ft. Subject to severe rockfall, rockslide, rock avalanche, and rock topple hazards. May be a source of high quality riprap and aggregate.

Qlsr **Recent landslide deposits (latest Holocene)**—Includes active and recently active landslides with fresh morphological features. Deposit is a heterogeneous unit consisting of unsorted, unstratified rock debris, gravel, sand, silt, and clay. Texture and clast lithology dependent upon source area. Includes rotational landslides, translational landslides, and complex slump-earth flows. Thickness probably a maximum of about 75 ft. Prone to renewed or continued landsliding, and also suggestive of the type of environment which may produce landslides in the current climatic regime. May be susceptible to settlement when loaded and to hydrocompaction and subsidence when derived from evaporites or Maroon Formation.

Qls **Landslide deposits (Holocene and Pleistocene)**—Highly variable deposits similar in texture and lithology to recent landslide deposits (Qlsr). Deposits range in age from historic to middle or perhaps even early Pleistocene, but do not exhibit widespread fresh morphological features suggestive of movement in the past one or two decades. Includes rotational landslides, translational landslides, complex slump-earth flows, and extensive slope-failure complexes. Maximum thickness possibly 250 ft. Unit may be subject to renewed landslide activity, but deeply dissected deposits probably are stable. May be prone to settlement when loaded. Deposits derived from evaporitic rocks or Maroon Formation may be susceptible to hydrocompaction and subsidence.

Qco **Older colluvium (Pleistocene)**—Includes various types of older deposits that were transported primarily by gravity, but area is not subject to significant continued depositional activity. Occurs on ridge lines, drainage divides, and hill slopes on valley walls as erosional remnants of formerly more extensive deposits. Texture, bedding, and clast lithology similar to colluvium (Qc). Maximum thickness about 25 ft. Where fine-grained may be subject to hydrocompaction, piping, and settlement.

Qlso **Older landslide deposits (Pleistocene and late Pliocene?)**—Landslide deposits dissected by erosion that lack distinctive landslide morphologic features. Similar in texture, bedding, sorting, and clast lithology to recent landslide deposits (Qlsr). Type of landslide movement not identifiable due to eroded character of deposits. Maximum thickness estimated at about 60 ft. Probably not prone to reactivation unless significantly disturbed by construction activities.

ALLUVIAL AND COLLUVIAL DEPOSITS—**Silt, sand, gravel, and clay in stream channels, flood-plains, and adjacent hill slopes along tributary valleys. Depositional processes in stream channels and on flood plains primarily alluvial, while colluvial and sheet-wash processes commonly dominant on hill slopes and along the hill slope/valley floor boundary.**

Qac **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Sediments in tributary valleys of small perennial and intermittent streams deposited by alluvial and colluvial processes. Chiefly stream-channel, low terrace, and flood-plain deposits along valley floors, with colluvium and sheet wash common on valley sides. Deposits of alluvium and colluvium probably are interfingered. Locally includes younger debris-flow deposits and also lacustrine deposits associated with man-made reservoirs and ponds. Alluvium typically composed of moderately well to well sorted, stratified, interbedded sand, pebbly sand, and sandy gravel, but colluvium may range to poorly sorted, unstratified or poorly stratified clayey, silty sand, bouldery sand, and sandy silt. Varied clast lithologies dependant upon type of rock within source area. Thickness commonly 5 to 20 ft, with maximum thickness estimated at about 40 ft. Low-lying areas are subject to flooding. Valley sides prone to sheet wash, rockfall, and small debris flows. Deposits derived from Mancos Shale may contain expansive clays susceptible to shrink-swell problems. Deposits derived from evaporitic rocks may be subject to settlement, piping, and hydrocompaction. May be a source of aggregate.

Qaco **Older alluvium and colluvium undivided (Pleistocene)**—Deposits of undifferentiated alluvium and colluvium that underlie terraces and hill slopes adjacent to small perennial and intermittent streams. Texture, bedding, clast lithology, and sorting similar to undivided alluvium and colluvium (Qac). Thickness to about 30 ft. May be prone to sheet wash and rockfall. May be a source of aggregate.

GLACIAL DEPOSITS—**Gravel, sand, silt, and clay deposited by ice in moraines.**

Qti **Till (late and middle Pleistocene)**—Heterogenous deposits of gravel, sand, silt, and minor clay deposited by ice in lateral, end, and ground moraines in the northwest corner of the quadrangle in Dry Possum Creek and in two tributaries to Mitchell Creek. End and lateral moraines are commonly hummocky, steep-sided, and bouldery, and have closed depressions encompassed by ridges. Moraine crests are moderately well preserved, but outermost lateral moraine on east side of Dry Possum Creek is weathered and its crest is rounded. Lower limit of glaciation at an altitude of about 9,400 ft. Terminal moraines in both tributaries of Mitchell Creek are narrowly breached by stream erosion, whereas the terminal moraine in Dry Possum Creek has been modified considerably by stream erosion. Although glacial deposits are not mapped within No Name Creek, glaciers may have extended into the quadrangle about one mile down the creek from the northern boundary of the quadrangle, based on the geomorphic character of the canyon and the presence of till immediately north of the quadrangle. Unit is dominantly unsorted or poorly sorted, unstratified or poorly stratified, matrix-supported bouldery, pebble and cobble gravel with a matrix of silty sand. May locally be clast-supported where composed mostly of gravel. Clasts are typically angular to round pieces of Precambrian and lower Paleozoic bedrock that occasionally exceed 10 ft in length. Unit probably in part of Pinedale age (approximately 12–35 ka, Richmond, 1986), but some of the outermost moraines, particularly in Dry Possum Creek, are probably of Bull Lake age or perhaps even of pre-Bull Lake age. Maximum thickness estimated at about 240 ft. May be prone to landsliding. May be a source of aggregate.

LACUSTRINE DEPOSITS—**Organic-rich silty clay, silt, and sand deposited in a lacustrine environment within Spring Valley.**

Ql — **Lacustrine deposits**—Well stratified deposits of medium to dark gray, organic-rich, well sorted silty clay and silt, and medium red brown, coarse sand deposited in a lacustrine environment within Spring Valley. Unit generally very poorly exposed except in a depression excavated through the water table to provide for stock watering in the SW1/4NW1/4 of section 29. According to Calvin Cox (1994, oral communication), a lake existed in Spring Valley until near the end of the last century. His ancestors hand excavated a ditch at the northwest end of Spring Valley to drain the lake and then farmed the exposed lake bottom to demonstrate agricultural use of the land for homesteading purposes. Land ownership was transferred from the federal government to his ancestor in 1896, therefore dewatering of the lake occurred prior to that year. The lake in Spring Valley did not result from landsliding, glaciation, or faulting which blocked the outlet, but rather the valley floor apparently subsided, perhaps as a result of diapirism in the underlying evaporite-bearing formations. Minimum thickness as determined by a test hole hand augered in the excavated depression is 8.5 ft. Maximum thickness unknown. May be prone to settlement when loaded.

EOLIAN DEPOSITS—**Silt, sand, and clay deposited by wind on level to gently sloping surfaces.**

Qlo — **Loess (late and middle ? Pleistocene)**—Slightly clayey, sandy silt and silty, very fine sand deposited and preserved on level to gently sloping surfaces. Typically unstratified, friable, and plastic or slightly plastic. Sand grains mostly of fine and very fine sizes, and sometimes frosted. Deposition occurred during at least two periods of eolian activity. Fairer and others (1993) mapped a single sheet of loess as occurring on deposits equivalent to younger and intermediate terrace alluvium (Qty and Qtm) in the Storm King Mountain quadrangle immediately west of the Glenwood Springs quadrangle, but mappable deposits of loess were not identified overlying these units on this quadrangle, perhaps because of the urban development which has occurred on these surfaces. At least one and perhaps two sheets of loess overlie older debris flow deposits (Qdfo) which rest on older terrace deposits (Qto) near West Glenwood Springs. In the southeast part of the quadrangle two or more sheets of loess are preserved overlying basalt and Maroon Formation and have been dryland farmed during the past. Mapped distribution of loess as depicted on this map is approximate due to the poor geomorphic expression of loess. Fairer and others (1993) suggest most loess was derived from floodplain sediments of the Colorado River and its tributaries, but recognize that outcrops of Tertiary siltstone and mudstone in the Piceance Basin and extensive areas of exposed sandstone in the Canyonands area of southeastern Utah may also have served as source areas for loess deposited in this part of Colorado. Thickness about 5 to 12 ft. Low density loess may be prone to settlement when loaded, and to hydrocompaction and piping when wetted. Highly erodible.

SINTER DEPOSITS—**Chemical sediment deposited by a mineral spring.**

Qtu — **Tufa (Holocene and Pleistocene?)**—Low density, porous chemical sedimentary rocks consisting of calcium carbonate precipitated from mineral-charged spring, ground, and surface water. Occurs as massive ledges and as a gravel-cementing material north of the Colorado River in and near West Glenwood Springs. Large bed of tufa below the Glenwood Springs golf course forms a prominent, continuous outcrop about 0.6-mi long which caps older terrace alluvium (Qto). Much of this ledge is resistant to erosion and forms near vertical outcrops, but other areas are easily eroded and in one instance a roadcut into tufa has been protected by a thin layer of reinforced concrete grout to reduce spalling problems. Another ledge of tufa overlies older debris flow deposits (Qdfo) in lower Oasis Creek. A bench of tufa beneath the rest area on Highway I-70 in West Glenwood Springs includes an organic-rich layer of clayey, sandy silt and peat which has been submitted to USGS for carbon-14 dating. The sequence overlies younger terrace alluvium (Qty). Small, unmapped, discontinuous areas of tufa-cemented gravel were noted within both older debris flow deposits (Qdfo) and older terrace alluvium (Qto) near the mouth of Oasis Creek and in adjacent areas. Tufa deposition is associated with both cold-water and hot-water springs. A cold-water spring with small active tufa mound occurs in Mitchell Creek above the Glenwood Springs fish hatchery. Thermal waters were encountered during 1993 in an excavation for a home at the base of the prominent tufa ledge west of Glenwood Springs (location indicated on map as thermal spring). Tufa deposits also occur near Hobo hot springs in the SW1/4 SW1/4 sec. 4, T. 6 S., R. 89 W. Tufa deposition may have initiated at least as early as the Pleistocene, and has continued at one or another location intermittently to the present.

UNDIFFERENTIATED DEPOSITS

Q **Undifferentiated surficial deposits (Quaternary)**—Shown only on cross sections.

BEDROCK

Tb **Basalt (Miocene)**—Multiple flows of basalt, olivine basalt, and andesitic basalt, interbedded with occasionally tuffaceous, commonly calcareous, fluvial siltstone and sandstone, lacustrine claystone, volcanic ash, and volcanic agglomerate. Interbedded sedimentary rocks. Flow rocks range from massive to highly vesicular, with amygdules of calcite and iron-rich clay. Groundmass is dominantly plagioclase and pyroxene with lesser but varying amounts of olivine, glass, pigeonite, augite, and magnetite. Trace minerals include apatite, iddingsite, and hematite. Phenocrysts generally olivine or plagioclase.

Basalt on and immediately south and southeast of Lookout Mountain, along with basalt overlying the Grand Hogback west of the Roaring Fork River, were mapped by Larson and others (1975) as Group 2 rocks. Larson and others (1975) report a whole rock K-Ar age date of 10.1 ± 0.5 Ma for a flow on Lookout Mountain, and suggest they range in age from 9 to 14 Ma. Group 2 rocks in the southwest part of the quadrangle thicken and rise in elevation southward towards Sunlight Peak, about 9 mi south of the quadrangle, which may be near their source area (Bass and Northrop, 1963). The source area for Group 2 rocks on Lookout Mountain has not been identified. Distribution of Group 2 rocks suggests lavas flowed from their source areas into a broad ancestral Roaring Fork River valley which had gently to moderately sloping valley walls. A sequence of interbedded pebble and cobble gravel, silty sand, and sandy silt that is strongly oxidized at the base of the exposure apparently overlies Group 2 rocks in a small gravel pit in the N1/2N1/2NE1/4 sec. 30, T. 6 S., R. 89 W. It contains abundant, well rounded clasts of granodiorite, quartz monzonite, and granite, many of which are grussified. Percentage of basaltic clasts increases from zero at base of exposure to about 30 percent in upper unit exposed in highwall. B. Bryant (1994, oral communication) believes part of the clasts were derived from middle Tertiary rocks in the Aspen area, suggesting the existence of an ancestral Roaring Fork River valley at this location.

Basalt east of Roaring Fork River and west to northwest of Spring Valley was mapped by Larson and others (1975) as

Group 3 rocks, which have whole rock K-Ar age dates of 8.68 ± 0.4 Ma and 7.86 ± 0.4 Ma 8 to 10 mi southeast of the quadrangle. However, basalt collected from a roadcut exposure at the northwest end of Spring Valley during this study has a whole rock ^{40}Ar / ^{39}Ar age of 22.4 ± 0.3 Ma, well outside the chronology for this area established by Larson and others (1975).

Estimated maximum thickness about 240 ft, but typically is much thinner. May be a source of rockfall debris where exposed in steep cliffs. May be susceptible to subsidence or sink holes where lava tubes occur near land surface. Potential source of high quality riprap and aggregate.

Kmv

Mesaverde Group (Upper Cretaceous)—Shown only on cross section A—A'.

Km

Mancos, Niobrara, Frontier, and Mowry Formations, undivided (Upper and Lower Cretaceous)—Includes in ascending order from its base the Lower Cretaceous Mowry Shale, Upper Cretaceous Frontier Sandstone, a calcareous shale zone equivalent to the Upper Cretaceous Niobrara (Murray, 1966; Tweto and others, 1978), and Upper Cretaceous Mancos Shale, which constitutes the majority of the unit. Mowry Shale is a siliceous, gray to black shale about 50- to 70-ft thick that contains fish scales. Frontier Sandstone is a calcareous sandstone unit about 300-ft thick. Calcareous shale zone equivalent to the Niobrara Formation is about 900-ft thick (Murray, 1966; Bass and Northrop, 1963; Tweto and others, 1978). Mancos Shale is dominantly light to dark gray, carbonaceous shale that contains thin bentonite beds and is about 4,200-ft thick.

Unit is very poorly exposed in mapped area, and frequently covered by residuum, colluvium, landslides, sheet wash, or basalt. Contacts between formations generally not mappable in quadrangle. Deposition occurred primarily on continental slope in low energy depositional environments. Formation is prone to slope stability problems, and susceptible to shrink-swell problems where it contains expansive clays.

Kd

Dakota Sandstone (Lower Cretaceous)—Light gray to tan, medium to very coarse-grained, quartzose sandstone and conglomeratic sandstone interbedded with carbonaceous siltstone, sandstone, and shale. Sandstone commonly well sorted and silica cemented, with angular to subround sand grains. Conglomeratic clasts generally pebble-sized chert and quartz. Comprised of one to three fairly continuous sandstone beds that occasionally are overlain by lenses of conglomeratic sandstone which are prominent on aerial photographs. Thickness ranges from about 90 to 175 ft. Unit is conformable with and perhaps intertongues with overlying Mowry Shale. Upper contact is placed at the top of the uppermost quartzose sandstone beneath the Mowry Shale. Formation is generally well exposed and forms conspicuous cliffs. Locally crops out on the Grand Hogback as a window of steeply dipping sandstone surrounded by basalt flows. Probably deposited in a transgressive environment at or near the shoreline of a lower coastal plain and in shallow marine embayments (Fairer and others, 1993). Formation is an important producer of oil and gas in the Piceance Basin west of the quadrangle.

Jm

Morrison Formation (Upper Jurassic)—Pale green and maroon mudstone and shale with thin beds of silty sandstone in lower part that may be equivalent to Salt Wash Member in nearby areas (Murray, 1966). Includes thin, gray limestone beds which contain abundant specimens of Charophyta (Peck, 1957). Thickness variable, but averages about 400 to 500 ft. Very poorly exposed in mapped area, where it is frequently covered by residuum, colluvium, sheet wash, or basalt. Contact with overlying Dakota Sandstone is sharp and unconformable, but difficult to precisely locate except where well exposed. Contact drawn below the quartzose sandstone and carbonaceous beds of the Dakota. Probably deposited in a lacustrine-dominated fluvio-lacustrine environment (Fairer and others, 1993).

Je

Entrada Sandstone (Upper Jurassic)—Light gray to light orange, cross-bedded sandstone. Medium to very fine-grained and well sorted. Sand fraction mostly subrounded to well rounded quartz grains. Contact with overlying Morrison Formation is sharp and conformable, and is placed at the top of the bold outcrop of the lighter colored Entrada Sandstone. Thickness averages about 50 to 100 ft, but may vary significantly over a short distance. Poorly exposed in quadrangle.

Occasionally forms smooth, slick outcrop, but commonly covered by residuum, colluvium, sheet wash, or basalt. Cross-bed sets are large scale and are interpreted as resulting from eolian processes in extensive dune fields (Fairer and others, 1993). Basal few inches may include pebbles and very coarse sand comprised of chert and quartz thought to have accumulated as an eolian lag deposit on the Chinle Formation.

ŦRc **Chinle Formation (Upper Triassic)**—Thin, even-bedded, and structureless red beds consisting of dark reddish brown, orangish red, and purplish red, calcareous siltstone and mudstone with occasional thin lenses of light purplish red and gray limestone and limestone-pebble conglomerate. Excellent exposure in South Canyon Creek about 2 mi west of quadrangle described by Stewart and others (1972a) as including the 208-ft-thick upper Chinle Red Siltstone Member and a 17-ft-thick basal unit correlated with the lower Chinle Mottled Member. Dubiel (1992) recognized a very thin, basal sandstone equivalent to the Gartra Member at this locality and stated that contacts between the Gartra Member and mottled strata are gradational, as is the contact between the mottled strata and the overlying red siltstone. Very poorly exposed in quadrangle. Formation is partially exposed in roadcut in Threemile Creek canyon, but is covered by residuum, colluvium, sheet wash, or basalt in other areas. Total thickness of formation is about 225 ft, based on South Canyon Creek outcrop, but exposure in Threemile Creek canyon suggests formation may be thinner locally. Contact with overlying Entrada Sandstone is sharp and unconformable, and is placed where the light colored Entrada Sandstone is in contact with the redbeds of the Chinle. Dubiel (1992) suggests the upper Chinle red siltstone beds are lateral-accretion and floodplain deposits, while the basal conglomerate and sandstone of the Gartra Member were deposited as active channel-fill and valley-fill deposits. Dubiel (1992) describes numerous paleosols within the formation.

ŦRPsb **State Bridge Formation (Lower Triassic? and Permian)**—Pale red, grayish red, reddish brown, and greenish gray, micaceous siltstone, clayey siltstone, and minor sandstone with a prominent, thin bed of sandy dolomite and sandy limestone. Commonly contains white and dark green micas, and solid hydrocarbon. Murray (1958) proposed that the South Canyon Creek Dolomite Member of the Maroon Formation described by Bass and Northrop (1950) be included within the State Bridge Formation. Stewart and others (1972b) divide the State Bridge Formation into three members: an upper member and lower member separated by the South Canyon Creek Member.

Formation is very poorly exposed in the quadrangle, but an excellent exposure occurs along South Canyon Creek about 2 mi west of the quadrangle, where it has been examined by several investigators. Stewart and others (1972b) indicate the upper member is 55.6-ft thick, South Canyon Creek Member is 5.6-ft thick, and lower member is 98.5-ft thick for a total formation thickness of 159.7 ft. They describe the South Canyon Creek Member as including a 4-ft thick, greenish gray to light olive gray dolomite and a 1.6-ft thick, light to dark gray limestone (color dependant on amount of solid hydrocarbon) with prominent wavy or crinkled laminae. Bass and Northrop (1950; 1963) collected fossils from the South Canyon Creek Member that were of Permian age and suggested the wavy structure indicated an algal origin. Upper and lower members are dominantly pale red and grayish red siltstone with minor claystone and sandstone. Only exposure of the State Bridge Formation within the Glenwood Springs quadrangle is a roadcut in Threemile Creek canyon that is mostly covered by colluvium and sheet wash. At this location the formation is either very thin (less than about 50-ft thick) or is partially removed by an unrecognized fault. South Canyon Creek Member was not observed at this location.

Contact with overlying Chinle is gradational and sometimes difficult to accurately locate unless the Gartra Member of the Chinle is present. Top of the upper member of the State Bridge coincides with the base of the Gartra Member, or base of the Mottled Member if the Gartra is absent. There usually is a distinct color change from the orange-red color of the Mottled Member of the Chinle to the brick red color of the upper State Bridge. According to Bryant (1979) parallel oscillation ripple marks are diagnostic of the State Bridge Formation. Formation thickens significantly to south and east (Freeman, 1971).

Unit probably mainly deposited in a fluvio-lacustrine environment dominated by lacustrine processes, but the South Canyon Creek Member suggests a short-lived encroachment of an environment favorable for carbonate deposition.

PIPm

Maroon Formation and Weber Sandstone, undivided (Permian and Pennsylvanian)—Mainly red beds of sandstone, conglomerate, mudstone, siltstone, and claystone with minor, thin beds of gray limestone. Includes Schoolhouse Tongue of Weber Sandstone at top of formation (Bass and Northrop, 1963; Stewart and others, 1972b). Conglomerate contains pebble- and cobble-sized clasts. Commonly arkosic and very micaceous. Weber Sandstone Member consists of light gray to greenish black, grayish red, and pale reddish brown, fine-grained, feldspathic sandstone and conglomeratic sandstone which contains locally abundant interstitial and grain-coatings of solid hydrocarbon. Nodules of pyrite occasionally present in middle of Weber Sandstone Member. Total thickness about 3,000 to 4,000 ft, including the 150- to 175-ft-thick Weber Sandstone Member.

Maroon Formation red beds crop out in southwestern part of the quadrangle and are particularly well exposed on the valley walls of the Roaring Fork River. Exposures generally poor near Lookout Mountain. Weber Sandstone Member typically poorly exposed in the quadrangle, except in a roadcut in the canyon of Threemile Creek, where it is partially exposed. Contact with overlying State Bridge Formation is sharp and possibly unconformable, and is placed where the light-colored beds of the Schoolhouse Tongue of the Weber Sandstone contact the red beds of the State Bridge. Deposition probably occurred in braided streams and on adjoining flood plains and distal sheet-wash areas in a large, coalescing alluvial fan complex on the margin of the Eagle Basin in an arid or semi-arid climate (Johnson, 1987; Fairer and others, 1993).

Formation is prone to rockfall and rockslide hazards, especially where prominent bedding planes are developed in the red beds. Numerous landslides appear to have originated in the unit, particularly in the vicinity of Lookout Mountain, and along the west side of the Roaring Fork River north of Threemile Creek.

IPe

Eagle Valley Formation (Middle Pennsylvanian)—Interbedded reddish brown, gray, reddish gray, and tan siltstone, shale, sandstone, gypsum, and carbonate rocks. Unit represents a stratigraphic interval in which the red beds of the Maroon Formation intertongue with the dominantly evaporitic rocks of the Eagle Valley Evaporite and includes rock types of both formations. Thickness variable, ranging from about 500 to 1,000 ft. Generally poorly exposed. Unit conforms and intertongues with overlying Maroon Formation and underlying Eagle Valley Evaporite. Contact with Maroon Formation placed at top of uppermost evaporite bed or light-colored clastic bed, and below base of thick sequence of red beds. Deposited in Eagle Basin on margin of evaporite basin at distal end of coalescing alluvial fan complex and in submarine environment within the evaporite basin.

May be susceptible to subsidence, sinkhole development, compaction, piping, and corrosion problems where evaporitic rocks occur near land surface.

IPee

Eagle Valley Evaporite (Middle Pennsylvanian)—Sequence of evaporitic rocks consisting mainly of gypsum, anhydrite, halite, and traces of potash salts interbedded with light colored, fine-grained clastic rocks, thin carbonate beds, and conglomerate. Beds commonly intensely folded, faulted, and plastically deformed by diapirism, flowage, load metamorphism, hydration of anhydrite, and Laramide tectonism (Mallory, 1971). Generally poorly exposed in quadrangle except in recent alluvial cuts, man-made exposures, and stacks, which are unique chimney-like landforms that are well developed west of Roaring Fork River. Stacks are typically composed of yellowish brown, calcareous sandstone breccia and sandy limestone breccia cemented by orangish yellow to greenish yellow-brown calcareous siltstone, sandstone, and claystone. Total thickness of the Eagle Valley Evaporite ranges from about 1,200 to perhaps as much as 9,000 ft (Mallory, 1971).

Presence of a thick halite sequence at the southern boundary of the quadrangle is reported by Mallory (1966) based on an oil test well about 3 mi south of the quadrangle. The well encountered 60 ft of alluvial gravel, 2,065 ft of gypsum, anhydrite, and siltstone, and 935 ft of halite. Drilling stopped in halite, therefore total halite thickness is not known. The Cattle Creek anticline, which deforms not only bedrock but also Pleistocene deposits (Piety, 1981), is probably resultant from salt diapirism, expansion due to hydration of anhydrite (Mallory, 1966), or perhaps flowage of evaporite from beneath Spring Valley into the Roaring Fork Valley caused by release of lateral confining pressures as the river downcut into the evaporitic rocks.

Contact with overlying Eagle Valley Formation is conformable and intertonguing, and is defined as the base of the lowest red bed within the Eagle Valley Formation. Primarily deposited in evaporitic basin formed as the outlet for the sea within the Paleozoic Eagle Basin was restricted (Mallory, 1971). Most clastic sediments in formation likely resulted from transgressive and regressive fluvial and lacustrine deposition (Fairer and others, 1993), but Schenk (1987) reports subaerial deposition of eolian sandstone within the formation between Eagle and Wolcott.

Prone to development of solution cavities into which overlying fine-grained sediments may be piped. May be subject to compaction, settlement, and corrosion problems. May be prone to diapiric or hydration swelling.

IPeu **Eagle Valley Formation and Eagle Valley Evaporite,Undivided (Middle Pennsylvanian)**—Includes Eagle Valley Formation and Eagle Valley Evaporite on south wall of Glenwood Canyon where heavy forest cover and lack of outcrops obscures the contact between units. Upper and lower contacts of unit coincide with those of the Eagle Valley Formation at the top and with the Eagle Valley Evaporite at the base. Thickness highly variable, but averages about 2,000 ft. May be prone to subsidence, sink holes, compaction, settlement, and piping where evaporitic rocks lie near land surface.

IPb **Belden Formation (Lower Pennsylvanian)**—Medium gray to black and dark brown, calcareous and locally micaceous shale and coarse-grained gray fossiliferous limestone. Contains interbeds and lenses of fine-grained, micaceous, greenish-tan sandstone; gritstone (quartz arenite); coaly shale; and gypsum. Very fossiliferous. Bass and Northrop (1963) describe 258 fossil species including algae, foraminifera, anthozoans, bryozoans, brachiopods, pelecypods, gastropods, scaphopods, cephalopods, annelids, trilobites, ostracods, blastoids, crinoids, echinoderms, and vertebrate remains. Unit is 700- to 900-ft thick across study area.

Rarely forms discernable outcrop except where subjected to rapid erosion, as in a 70-ft-high exposure along the Scout Trail on Lookout Mountain east of Glenwood Springs. Normally forms a vegetated slope above the prominent cliffs of the underlying Leadville Limestone. Conformably overlain by a massive bed of gypsum which is the basal marker horizon of the overlying Eagle Valley Evaporite (Mallory, 1971). On the east side of study area the Belden Formation contains considerable gypsum, rendering identification of upper contact difficult due to lack of good exposures.

Deposited in the Eagle Basin which formed in the northwestern portion of the Central Colorado Trough between the Uncompahgre and Front Range elements of the Ancestral Rocky Mountains. Formed in a relatively low energy environment at a distance from source areas.

Ml **Leadville Limestone (Mississippian)**—Light to medium gray, bluish gray, massive, coarse to finely crystalline, fossiliferous micritic, limestone and dolomite. Contains lenses and nodules of dark gray to black chert as much as 0.3-ft thick in the lower one-third of the formation. Upper half of the formation contains coarse-grained oölites. Carbonate veins with disseminated silt-sized quartz grains are common. Top of unit contains collapse breccias, filled solution cavities, and a red to reddish purple claystone regolith (Molas Formation), all of which formed on a paleokarst surface. Very fossiliferous, including abundant crinoid and brachiopod fragments. Forms a prominent cliff and is frequently the cap rock of outcrops within Glenwood and tributary canyons. Upper contact is irregular and unconformable with overlying Belden Formation. Unit is 200-ft thick across study area. Formed in a marine environment in the sub-littoral zone by chemical precipitation and through the accumulation of biogenic and oölitic sediment.

Unit can be chemically pure and has been mined as metallurgical grade limestone in the northern half of the quadrangle. Also a source of riprap and aggregate. Modern solution features including caves and solution pockets are common in these rocks. Unit may be susceptible to sink holes and subsidence where karst features occur near land surface. May be a source of rockfall debris where exposed in cliffs.

Dc

Chaffee Group (Upper Devonian)—Sequence composed of green shale, quartzite, dolomite, limestone, and dolomitic sandstone. Consists of three named formations, from top to bottom: Gilman Sandstone, Dyer Dolomite, and Parting Formation. Total thickness of the Chaffee Group in Glenwood Canyon as measured by Soule (1992) is 252.5 ft.

Gilman Sandstone consists of tan to yellow, laminated, fine to very fine-grained quartz arenite and dedolomitic limestone. Highly variable in lithology and thickness across study area. Predominantly a 16-ft thick calcareous sandstone on the southeast flank of the White River Uplift. Becomes an oxidized dolomite (dedolomite) with thicknesses less than 1 ft to the west near Glenwood Springs. Sandstone phase consists of rounded to sub-rounded quartz grains which are well sorted. Laminae are generally less than 1 inch in thickness consisting of zones of fine sand which locally display weak planar-tabular cross-bedding and minor load structures. Some laminae contain discontinuous lenses of quartz arenite with visible relict casts of carbonate rhombohedron. Limestone beds consist of a greater than 99 percent pure calcite-bearing dedolomitic limestone with minor hematite and quartz. Upper contact with the overlying Mississippian Leadville Limestone is unconformable. Tweto and Lovering (1977) suggest a water reworked, eolian origin for the Gilman Sandstone near Gilman. Most likely deposited in a changing environment of very shallow water and periodic subaerial exposure in the supratidal (tidal flat) zone.

Dyer Dolomite is divided into two members on the White River Plateau. Upper Coffee Pot Member consists of crystalline, micritic dolomite, dolomitic gray shale, and micritic limestone. Somewhat sandy, especially near the top. Fossiliferous in places. Member is characterized by abundant rip-up clasts, intraformational breccia, and bioturbated bedding (Soule, 1992). Together with the Gilman Sandstone forms blocky slopes beneath the prominent cliff of overlying Leadville Limestone in canyon outcrops. Deposited predominantly in the uppermost intertidal to supratidal (tidal flat) zones in a changing environment of periodic subaerial exposure with influxes of shallow marine conditions. Lower Broken Rib Member consists of gray nodular crystalline limestone. Dyer Dolomite is abundantly fossiliferous with brachiopods dominant (34 species) (Bass and Northrop, 1963). Forms a very distinctive "knobbly-weathering" gray ledge above blocky slopes of the underlying Parting Formation in canyon outcrops. Formed in a shallow marine environment in the sub-littoral zone.

Parting Formation is variable in lithology across study area. In Glenwood Canyon it consists of white to buff, well-cemented, orthoquartzite with minor feldspar and rock fragments, micaceous green shale with discontinuous lenses of orthoquartzite, and sandy micritic dolomite. Formation contains limestone breccia and sandy, green shale on north end of quadrangle in vicinity of Windy Point. Thicknesses of orthoquartzite beds are consistent across study area ranging from 0.5 to 1.0 ft. Other beds show much greater variation in thickness. Forms a blocky slope with distinct ledges above prominent cliffs of underlying Manitou Formation. Bass and Northrop (1963) report fish remains collected from the Parting in Glenwood Canyon. Formed in a shallow marine environment.

MDr

Mississippian and Devonian rocks, undivided (Mississippian and Upper Devonian)—Includes rocks of the Leadville Limestone and Chaffee Group where it is not practicable to separate formations due to poor outcrop exposure, inaccessibility, or poorly defined marker horizons. These rocks occur between the Ordovician Manitou Formation below and the Pennsylvanian Belden Formation above. Thickness of combined unit is 450 ft. Combined unit may be susceptible to sink holes and subsidence where karst features occur near land surface.

Om

Manitou Formation (Lower Ordovician)—Formation consists predominantly of medium-bedded brown dolomite at the top with thin beds of gray flat-pebble limestone interbedded with greenish gray calcareous shale, sandstone, and brown-weathering limestone and dolomite in the lower portions. In Glenwood Canyon the unit is 155.8 ft thick according to Bass and Northrop (1963) and 167.3-ft thick as measured by Soule (1992).

Upper Tie Gulch Member consists of massive, micritic, brown and orange-weathering, crystalline, somewhat siliceous, dolomite and minor limestone. Member becomes somewhat sandy near the top. Member forms a consistent 50- to 90-ft thick, brown to orange colored cliff in Glenwood, No Name, and Grizzly Canyons rising distinctly above a gentler slope produced on the lower Manitou and Dotsero Formations. Some beds are glauconitic although considerably less so than the underlying beds of the Dead Horse Conglomerate Member. No fossils are known to occur in the Member. Upper contact with the overlying Devonian Chaffee Group is unconformable, occurring at a thin shale bed which may be the remains of a paleosol (Soule, 1992). Strong dolomitization and lack of marine fossils suggests that sediments of the Tie Gulch Member accumulated in the upper intertidal and/or lowermost supratidal (tidal flat) environments.

Lower Dead Horse Conglomerate Member consists mostly of thin-bedded, gray, flat-pebble limestone conglomerate, thin-bedded limestone, shaly limestone, and two beds of massive dolomitic orthoquartzite. Member is somewhat glauconitic, especially in the bottom portion. A diverse Lower Ordovician fossil fauna has been described from the Member by Bass and Northrop (1963) collected from outcrops in Glenwood Canyon. Base of member generally forms a continuous slope with underlying rocks of the Dotsero Formation. Upper portions of member frequently form an unbroken cliff with overlying rocks of the Tie Gulch Member in Glenwood, No Name, and Grizzly Canyons, rendering close inspection of upper contact difficult. Member most likely was deposited under fluctuating conditions and varying water depths in the intertidal and shallow marine environments. May be a source of rockfall debris.

€d

Dotsero Formation (Upper Cambrian)—Thinly-bedded, tan to gray silty and sandy dolomite, dolomitic sandstone, green dolomitic shale, limestone and dolomite conglomerate, limestone, and pinkish-light gray to very light gray and white to lavender-weathering algal limestone.

Upper Clinetop Member is a 5-ft-thick sequence of matrix-supported limestone pebble conglomerates with abundant rip-up clasts which occurs below a bed of stromatilitic limestone with well preserved algal-head crinkle structure. Upper contact of the Dotsero Formation in Glenwood Canyon is defined by an identified upper Cambrian fossil assemblage collected from the Clinetop Member as distinguished from a lower Ordovician fossil assemblage collected 3 ft above in conformably overlying limestone pebble conglomerates of the Manitou Formation (Bass and Northrop, 1953). The Clinetop algal biostrome and bounding limestone pebble conglomerates occur throughout a 400-square-mile area across the White River Plateau suggesting periods of high energy characteristic of the intertidal environment separated by a period of remarkable, wide-spread quiescence at the close of Cambrian time indicative of the uppermost intertidal to supratidal environment.

Glenwood Canyon Member consists of thinly-bedded dolomite, dolomitic sandstone, conglomeratic limestone, coarse-grained fossiliferous limestone, and dolomitic shale. Dolomitic beds contain abundant glauconite giving a greenish hue to float rocks and locally, sericite. Worm tracks and worm burrows (fucoids) are common, especially in the middle third of the member. Desiccation cracks are less common. These rocks generally form a vegetated slope above the prominent cliffs of the Sawatch Quartzite, however, they can be a cliff-former, especially in the deeper portions of Glenwood, No Name, and Grizzly Canyons. Member is 90-ft thick. Variation in lithologies and sedimentary structures in the member indicate a period of widely fluctuating depositional patterns ranging from near-shore shallow marine through intertidal to supratidal (tidal flat) environments.

€s

Sawatch Quartzite (Upper Cambrian)—White and buff to gray-orange, brown-weathering, vitreous orthoquartzite in beds from 1- to 3-ft thick. Locally contains beds of arkosic quartz-pebble conglomerate at base of unit resting unconformably on highly weathered Precambrian rocks. Basal hematite-stained, planar to tabular cross-bedded sandstone interbedded with quartzite is also observable in the map area. Map unit includes beds of massive, brown, sandy dolomite, which are a suggested equivalent of the Peerless Formation described by Tweto and Lovering (1977) and Bryant (1979) at Minturn and Aspen, respectively, and overlying beds of unnamed sandy dolomite and white dedolomitic quartzite. These upper beds are possibly disconformable with sediments of the Sawatch Quartzite below and the overlying Dotsero Formation. These sediments form a continuous cliff with the Sawatch Quartzite in Glenwood Canyon and cannot be mapped separately. Fossils are extremely rare to non-existent in these rocks. Total thickness of this combined unit is 500 ft. Primary sedimentary structure is poorly preserved in the Sawatch Quartzite which most likely originated as beach deposits or in shallow water of the littoral zone from sediment eroding off a highland in the vicinity of the Front Range (Tweto and Lovering, 1977). Peerless-equivalent rocks and unnamed overlying dolomitized sediments possibly formed in the intertidal or lowermost supratidal (tidal-flat) environment characterized by fluctuating water depth. Formation prone to rockfalls, rockslides, and rock avalanches. May be a source of aggregate.

O€r **Ordovician and Cambrian rocks, undivided (Upper Cambrian and Lower Ordovician)**—Includes rocks of the Sawatch Quartzite, Dotsero Formation, and Manitou Formations where it is not practicable to separate these rocks due to poor outcrop exposure, inaccessibility, or poorly defined marker horizons. Combined unit occurs between Precambrian rocks below and rocks of the Chaffee Group above. Combined unit is 745 ft in thickness.

PRECAMBRIAN ROCKS

Xg **Biotite Granite (Proterozoic)**—Generally dark gray and white speckled, medium to coarse-grained, equigranular granite and granodiorite, however, in the upper reach of No Name Canyon the granite is fine to medium-grained. Primary constituents are soda-rich anhedra of plagioclase, anhedra of microcline and perthite, and severely strained anhedra of quartz. Small blebs of quartz also occur within the feldspar crystals. Accessory minerals include interstitial anhedra of biotite and hornblende. Trace minerals are magnetite, apatite, sphene, epidote, chlorite, and zircon. Mafic xenoliths averaging about a foot in diameter are common in the granite. Samples of the granite examined under the petrographic microscope have a weak gneissic foliation defined by the alignment of the biotite and hornblende crystals.

Unit forms spectacular, well-jointed outcrops in Glenwood Canyon, however, in No Name Canyon exposures are more subdued in comparison to the surrounding foliated rocks. The granite contains numerous dikes and sills of white to pink pegmatite and aplite. Dikes and sills range from an inch to 10-ft wide and have lengths as much as a few hundred feet.

Lithological similarity of the biotite granite to granites exposed in the Aspen area (Bryant, 1979) and Sawatch Range (Wetherill and Bickford, 1965) indicate that the biotite granite (and other foliated igneous rocks) are of 1.6 to 1.7 Ga (Precambrian X age). Presence of foliation in these rocks indicates a syn- or post metamorphic origin for the intrusive rocks.

Unit is subject to rockslides and rockfalls in the canyons where it is exposed. May be a source of aggregate and riprap.

Xpgd **Porphyroblastic biotite granodiorite of No Name Canyon (Proterozoic)**—Matrix of the granodiorite is coarse-grained, inequigranular, and speckled in appearance, and consists of light redish pink orthoclase anhedra, white anhedra of plagioclase often dusted with secondary white mica and lesser amounts of epidote, and strained anhedra of quartz. The porphyroblasts are light red to pink, fresh, large (2 to 4 in. in length), euhedral, twinned crystals of orthoclase.

Biotite is the only accessory mineral, constituting about 20 percent by volume of the rock. Magnetite, apatite, and zircon occur in trace amounts. Petrographic examination indicates that the granodiorite has a gneissic texture.

In outcrops at Horseshoe Bend, a prominent bend in the Colorado River about 2,000 ft west of the junction of No Name Creek and the Colorado River, the orthoclase porphyroblasts are strongly aligned in a northwest-southeast direction. At this locality a purple to dark gray regolith is developed in the granodiorite for approximately 20 ft below the contact with the overlying Cambrian Sawatch Quartzite.

Rocks of similar lithology and texture have been described near Aspen (Bryant, 1979) and in the Sawatch Range (Stark and Barnes, 1935) and are thought to be approximately 1.6 to 1.7 Ga.

The porphyroblastic granodiorite may be a border phase of the entire syn- to post-metamorphic, intrusive event as it is the only unit that has been observed to have intrusive contacts with the older biotite-muscovite gneiss.

Unit may be subject to rockfalls and rockslides. Locally suitable for use as aggregate and riprap.

Xqm **Gneissic quartz monzonite of Mitchell Creek (Proterozoic)**—Predominantly light red to pink, fine to medium-grained, equigranular, foliated, quartz monzonite. Anhedra of microcline, microperthite, plagioclase, and severely strained, irregular shaped anhedra of quartz are the primary constituents. Quartz also occurs as chains of small blebs within discontinuous and anastomosing cataclastic microshears. Biotite, commonly replaced by chlorite, and muscovite are accessory minerals. The muscovite occurs predominately in the cataclastic microshears. Trace minerals include magnetite, hematite, leucoxene, and apatite. This unit like the above described igneous rocks is thought to be 1.6 to 1.7 Ga. May be a source of rockfalls and rockslides. Locally acceptable for use as aggregate and riprap.

Xmgn **Biotite-muscovite gneiss (Proterozoic)**—Dark gray to black, well to poorly foliated, biotite-muscovite gneiss composed primarily of fine-grained quartz, orthoclase, plagioclase, and as much as 35 percent biotite and muscovite. Biotite is commonly partially replaced by chlorite. In some localities the gneiss is coarse grained and contains distinct 1 in. diameter aggregates of white muscovite. Quartz and feldspar podiform segregations that range from a few inches to 3-ft long and from less than an inch to 0.5-ft wide are common throughout the gneiss. Migmatitic layers of granite gneiss in bands ranging from approximately 1 in.- to 3-ft thick are locally abundant.

White and pink pegmatite and aplite zones are common within the gneiss and can locally comprise most of the mapped gneiss unit. Where pegmatite units are mappable they are shown by a stippled pattern. Pegmatite units within the biotite-muscovite gneiss are generally composed of large, white, euhedral feldspars, muscovite, anhedral to euhedral, red garnets, dendritic aggregates and solitary crystals of black tourmaline, and oxidized specular hematite.

Several studies of the Precambrian in Colorado have established an accepted chronology (Bryant, 1979). Sedimentary rocks, most likely shales and graywackes, were deposited in this area from about 2.0 to 1.7 Ga. The sediments were metamorphosed and, during the waning stages of metamorphism, intruded by granitic rocks of variable composition and texture about 1.6 to 1.7 Ga. May be subject to rockfalls and rockslides. May be acceptable for use as aggregate and riprap.

ECONOMIC GEOLOGY

Mineral commodities with possible economic potential in the quadrangle include high-calcium limestone, and to a lesser degree, base metals. Limestone has been quarried in the quadrangle from three principal locations, all of which are less than one mile from the city of Glenwood Springs. One of these limestone quarries retains an active permit status (1994) even though there has been no mining in recent years. One small occurrence of oxidized lead-zinc ore was evaluated in 1944 by the United States Bureau of Mines under the War Minerals Program. This property is located near Windy Point on the north end of the quadrangle.

The Mississippian Leadville Limestone crops out extensively on the White River Plateau and has been suggested as a source of high-calcium limestone. CF & I Steel Corporation, Pueblo, has identified an area near Willow Peak on the adjacent Broken Rib Creek quadrangle that has been proven by core drilling to contain a sizeable resource of metallurgical limestone (Wark, 1980). Specific quality parameters pertaining to limestone feedstock for steel making applications (high calcium content—over 97 percent $CaCO_3$ and low silica content—less than 1 percent SiO_2) are frequently attainable in the Leadville Limestone, particularily in its upper part where dolomitization is less prevalent and away from the chert-bearing lower zones.

It is possible that zones of high-calcium limestone exist in the Devonian age Chaffee Group, but this is less likely. Any area within the quadrangle where the Leadville Limestone or other high-calcium rocks occur without appreciable overburden may be a target area for limestone development.

Lead and zinc minerals with minor copper and silver have been identified within the quadrangle near Windy Point (Strong Mine). The deposit was assayed at 24 percent zinc, 8.7 percent lead, 0.17 percent copper, and 0.81 troy ounces per short ton silver (Heyl, 1964). The minerals occur in small but rich "pods" within a fissure vein which strikes N. 50° E. and dips 44° NW. The mineralization is hosted in carbonate rocks of the Devonian Chaffee Group and the Mississippian Leadville Limestone. The ore consists of a mixture of lead and zinc minerals which are generally oxidized. At the time of the initial assessment of this deposit in 1944 by the U.S. Bureau of Mines, the ore was observed to occur only above a caved adit and in two small open cuts. When this site was visited in 1994 for this mapping project no ore was apparent in one recently driven adit (20 ft) nor was any of the described mineralization observable in surface exposures. This suggests a very discontinuous nature for these occurrences and, at best, a minor resource for this site. Other areas of lead-zinc-silver mineralization may occur in the quadrangle, however, none was observed during the course of field mapping. Other deposits similiar to those at Windy Point, if they do exist, are expected to be small and most likely sub-economic.

There are several thermal springs mostly associated with the Leadville Limestone and other carbonate rocks. Thermal springs near the city of Glenwood Springs are characterized by their high salinity, 18,000 to 22,0000 ppm sodium, temperatures ranging from 44° to 52°C, and flow rates of up to 5,000 liter per minute (Cappa and Hemborg, 1995).

Whole-Rock Analyses of the Glenwood Springs Quadrangle

	Percent											
Sample ID	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	Cr_2O_3	P_2O_5	TiO_2	LOI*
GL-100	47.0	14.0	8.83	6.53	3.15	1.42	13.40	0.16	0.02	1.05	2.550	0.25
GL-146	47.3	14.4	7.40	8.35	2.92	2.05	11.40	0.15	0.03	0.67	1.770	1.95
GL-165B	49.5	15.1	8.11	6.76	2.96	1.23	11.80	0.15	0.03	0.46	1.520	1.70
GL-221	49.2	15.7	7.72	7.05	2.70	1.26	12.00	0.16	0.03	0.45	1.520	2.20
GL-306	50.2	15.2	7.17	6.62	3.12	2.31	11.10	0.15	0.03	0.66	1.810	0.75
GL-25	51.1	14.9	7.69	6.69	2.92	2.10	10.30	0.14	0.03	0.55	1.570	1.85
GMC-2	73.7	13.0	1.12	0.47	3.10	4.44	2.89	0.02	0.04	0.05	0.288	0.50
GNN-5	65.1	15.8	3.17	2.58	3.78	2.34	4.76	0.07	0.01	0.24	0.508	0.80
GCR-1	64.5	15.5	1.32	2.87	2.84	3.19	6.79	0.06	0.03	0.16	0.670	1.70
GNN-1	62.8	15.6	3.51	2.22	3.35	2.71	6.48	0.08	0.01	0.42	0.945	1.10

* Loss On Ignition

SAMPLE DESCRIPTIONS

GL-100: Coarse grained basalt flow exposed in roadcut at northwest end of Spring Valley: NW1/4NE1/4SE1/4 Sec. 24; T. 6 S.; R.89 W.

GL-146: Aphanitic basalt flow on ridge crest east of Glenwood Springs: SE1/4NE1/4SE1/4 Sec. 15; T. 6 S.; R. 89 W.

GL-165B: Aphanitic basalt flow exposed in quarry on Lookout Mountain: SE1/4SE1/4SE1/4 Sec. 12; T. 6 S.; R. 89 W.

GL-221: Vesicular, aphanitic basalt flow capping hilltop south of road into Paradise Valley from Mountain Springs Ranch: S1/2SW1/4NE1/4 Sec. 18; T. 6 S.; R. 89 W.

GL-306: Basalt flow exposed in roadcut in 10 acre subdivision west of north end of Spring Valley: NW1/4SE1/4SE1/4 Sec. 24; T. 6 S.; R. 89 W.

GL-25: Outcrop of basalt adjacent to road to Hughes Reservoir from Mountain Springs Ranch: SE1/4SW1/4SE1/4 Sec. 19; T. 6 S.; R. 89 W.

GMC-2: Gneissic quartz monzonite, Mitchell Creek: NE1/4NE1/4 Sec. 27; T. 5 S.; R. 89 W.

GNN-5: Medium-grained granite, 2.9 mi up No Name Creek just before aqueduct.

GCR-1: Biotite muscovite gneiss from outcrop on north side of Colorado River between No Name and Grizzly Canyons.

GNN-1: Coarse-grained, porphyroblastic granodiorite, Horseshoe Bend: SW1/4NE1/4 Sec. 3; T. 6 S.; R. 89 W.

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COLORADO GEOLOGICAL SURVEY
DIVISION OF MINERALS AND GEOLOGY
DEPARTMENT OF NATURAL RESOURCES

OPEN FILE MAP 95-3
GEOLOGIC MAP OF THE GLENWOOD SPRINGS
QUADRANGLE, GARFIELD COUNTY, COLORADO
Booklet accompanies map

Base from U.S. Geological Survey, 1987
10,000-foot grid bases on Colorado coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 13

UTM GRID AND 1987 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

GN MN 1°24′ 25 MILS 12° 213 MILS

SCALE 1:24 000

1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

COLORADO
QUADRANGLE LOCATION

Geology mapped in 1993 and 1994; assisted by Peter L. Stelling in 1994.

CONDENSED DESCRIPTION OF MAP UNITS

The complete description of map units and references is in the accompanying booklet.

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af — **Artificial fill (latest Holocene)**

ALLUVIAL DEPOSITS

ALLUVIAL DEPOSITS—Sediments deposited in stream channels, flood plains, terraces, debris fans, and sheet-wash areas

Qa — **Stream-channel, flood plain, and low-terrace deposits (Holocene and late Pleistocene)**—Mostly poorly sorted, clast-supported gravel in a sandy or silty matrix up to about 15 ft above modern stream level

Qdfy — **Younger debris-flow deposits (Holocene)**—Poorly sorted, clast- and matrix-supported, pebble and cobble gravel in a sandy silt or silty sand matrix. Distal fan areas are finer grained. Deposited on active fans

Qsw — **Sheet-wash deposits (Holocene and late Pleistocene)**—Bedded deposits of gravelly sand, sandy silt, and clayey silt

Qdfm — **Intermediate debris-flow deposits (Holocene and late Pleistocene)**—Poorly sorted gravels found 15–40 ft above adjacent streams. Similar in texture to younger debris-flow deposits

Qty — **Younger terrace alluvium (late Pleistocene)**—Mostly poorly sorted, clast-supported gravels, occasionally bouldery, pebble and cobble gravel with a sand matrix underlying terraces that range from about 19–56 ft above modern stream level. May include fine-grained overbank deposits

Qtm — **Intermediate terrace alluvium (late Pleistocene)**—Deposits texturally similar to younger terrace alluvium. Underlies terraces about 58–95 ft above modern stream level

Qdfo — **Old debris-flow deposits (late, middle, and early? Pleistocene)**—Remnants of long-inactive debris fans found on ridge lines, mesas, and valley floors 40–320 ft above adjacent streams. Similar in texture to younger debris-flow deposits

Qto — **Older terrace alluvium (middle Pleistocene)**—Deposits texturally similar to younger terrace alluvium. Underlies terraces about 110–130 ft above modern stream level

Qtt — **Oldest terrace alluvium (middle Pleistocene)**—Deposits similar in texture to younger terrace alluvium. Underlies a terrace west of Glenwood Springs airport about 220–360 ft above the Roaring Fork River

QTg — **High-level gravel (early Pleistocene or Pliocene)**—Includes a single, very poorly exposed deposit of rounded river gravel found about 1,500 ft above the Colorado River near the north quarter-corner of sec. 7, T. 6 S., R. 88 W.

COLLUVIAL DEPOSITS

COLLUVIAL DEPOSITS—Sediments on valley sides, valley floors, and hill slopes mobilized, transported, and deposited primarily by gravity

Qc — **Colluvium (Holocene and late Pleistocene)**—Matrix- and clast-supported, pebble to boulder gravel in a sandy silt matrix. Locally fine grained

Qt — **Talus (Holocene and late Pleistocene)**—Angular, cobbly and bouldery rubble derived from bedrock outcrops and transported as rockfalls, rockslides, rock avalanches, and rock topples. Deposits marked by triangular pattern in No Name Creek indicate two very large, rapid rotational rockslides or rock topples

Qlsr — **Recent landslide deposits (latest Holocene)**—Includes active and recently active landslides with fresh morphological features. Heterogeneous unit consisting of unsorted, unstratified rock debris, gravel, sand, silt, and clay

Qls — **Landslide deposits (Holocene and Pleistocene)**—Similar in texture to recent landslide deposits

Qco — **Older colluvium (Pleistocene)**—Highly variable deposits texturally similar to colluvium, but not presently active

Qlso — **Older landslide deposits (Pleistocene and late Pliocene?)**—Landslide deposits dissected by erosion that lack distinctive landslide morphology. Similar in texture to recent landslide deposits

ALLUVIAL AND COLLUVIAL DEPOSITS

ALLUVIAL AND COLLUVIAL DEPOSITS—Sediments in stream channels, flood-plains, and hill slopes along tributary valleys

Qac — **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Moderately well to well sorted, stratified, interbedded sand, pebbly sand, and sandy gravel to poorly sorted, unstratified or poorly stratified clayey, silty sand, bouldery sand, and sandy silt

Qaco — **Older alluvium and colluvium, undivided (Pleistocene)**—Deposits texturally similar to alluvium and colluvium, undivided, that underlie terraces and hill slopes above the floor of tributary valleys

GLACIAL DEPOSITS

Qti — **Till (late and middle Pleistocene)**—Heterogenous deposits of gravel, sand, silt, and minor clay deposited in lateral, end, and ground moraines

LACUSTRINE DEPOSITS

Ql — **Lacustrine deposits**—Well stratified deposits of medium to dark gray, organic-rich, silty clay and silt, and medium red brown, well sorted, coarse sand deposited in Spring Valley

EOLIAN DEPOSITS

Qlo — **Loess (late and middle? Pleistocene)**—Slightly clayey, sandy silt and silty, very fine sand deposited by wind on level to gently sloping surfaces. Usually unstratified, friable, and plastic or slightly plastic

SINTER DEPOSITS

Qtu — **Tufa (Holocene and Pleistocene?)**—Low density, porous calcium carbonate deposits precipitated from mineral-charged spring water

UNDIFFERENTIATED DEPOSITS

Q — **Undifferentiated surficial deposits (Quaternary)**—Shown only on cross sections

BEDROCK

Tb — **Basalt (Miocene)**—Multiple flows of basalt, olivine basalt, and andesitic basalt, interbedded with tuffaceous, fluvial siltstone and sandstone, lacustrine claystone, volcanic ash, and volcanic agglomerate. A whole rock sample of basalt exposed in a roadcut at the northwest end of Spring Valley was age dated at 22.4 ± .3 Ma using $^{40}Ar/^{39}Ar$ method (L. Snee, personal communication, 1995)

Kmv — **Mesaverde Group (Upper Cretaceous)**—Shown only on cross section A—A′

Km — **Mancos, Niobrara, Frontier, and Mowry Formations, undivided (Upper and Lower Cretaceous)**—Includes in ascending order: siliceous, gray to black shale of the Lower Cretaceous Mowry Shale, the calcareous Upper Cretaceous Frontier Sandstone, a calcareous shale zone equivalent to the Upper Cretaceous Niobrara, and the dominantly light to dark gray, sometimes bentonitic, carbonaceous shale unit that comprises the Upper Cretaceous Mancos Shale

Kd — **Dakota Sandstone (Lower Cretaceous)**—Light gray to tan, medium to very coarse-grained, quartzose sandstone and conglomeratic sandstone interbedded with carbonaceous siltstone, sandstone, and shale

Jm — **Morrison Formation (Upper Jurassic)**—Pale green and maroon mudstone and shale and gray limestone. Thin beds of silty sandstone in lower part

Je — **Entrada Sandstone (Upper Jurassic)**—Light gray to light orange, cross-bedded sandstone. Medium to very fine grained and well sorted

TRc — **Chinle Formation (Upper Triassic)**—Thin, even bedded, dark reddish brown, orangish red, and purplish red, calcareous siltstone and mudstone with occasional thin lenses of light purplish red and gray limestone and limestone-pebble conglomerate

TRPsb — **State Bridge Formation (Lower Triassic? and Permian)**—Includes upper and lower members composed of pale red, grayish red, reddish brown, and greenish gray, micaceous siltstone, clayey siltstone, and minor sandstone that are separated by the South Canyon Creek Member, a prominent, thin bed of sandy dolomite and sandy limestone

PIPm — **Maroon Formation (Permian and Pennsylvanian)**—Mainly reddish brown sandstone, conglomerate, mudstone, siltstone, and claystone with minor, thin beds of gray limestone. Includes Schoolhouse Tongue of Weber Sandstone at top of formation

IPe — **Eagle Valley Formation (Middle Pennsylvanian)**—Intertonguing sequence of Maroon Formation and Eagle Valley Evaporite

IPee — **Eagle Valley Evaporite (Middle Pennsylvanian)**—Evaporitic sequence of gypsum, anhydrite, halite, and minor potash salts interbedded with fine-grained clastic rocks, thin carbonate beds, and conglomerate. Commonly intensely folded, faulted, and plastically deformed

IPeu — **Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian)**—Includes Eagle Valley Formation and Eagle Valley Evaporite where contact between units is not mappable

IPb — **Belden Formation (Lower Pennsylvanian)**—Medium gray to black, calcareous shale and fossiliferous limestone with interbeds of fine-grained micaceous sandstone, gritstone, coaly shale, and gypsum

Ml — **Leadville Limestone (Mississippian)**—Gray to bluish gray, coarse to finely crystalline limestone and dolomite. Abundant chert nodules in lower part of formation

Dc — **Chaffee Group (Upper Devonian)**—Includes in ascending order: Parting Formation—white to buff orthoquartzite, green shale and gray dolomite; Dyer Dolomite—limestone and dolomite; and Gilman Sandstone—tan to yellow, fine-grained dolomitic sandstone

MDr — **Mississippian/Devonian rocks-undivided (Mississippian and Upper Devonian)**

Om — **Manitou Formation (Lower Ordovician)**—Flat-pebble limestone conglomerate, brown and tan crystalline dolomite, and greenish-gray calcareous shale

€d — **Dotsero Formation (Upper Cambrian)**—Thin bedded, brown to tan sandy dolomite and dolomitic sandstone with abundant glauconite and pinkish light-gray to light-gray algal limestone and conglomerate

€s — **Sawatch Quartzite (Upper Cambrian)**—White to buff, massive, medium-grained orthoquartzite and arkosic quartz-pebble conglomerate. Unit includes Peerless Formation equivalent sandy dolomites, white quartzites, and quartzose sandstones

O€r — **Ordovician and Cambrian rocks, undivided (Upper Cambrian-Lower Ordovician)**

PRECAMBRIAN ROCKS

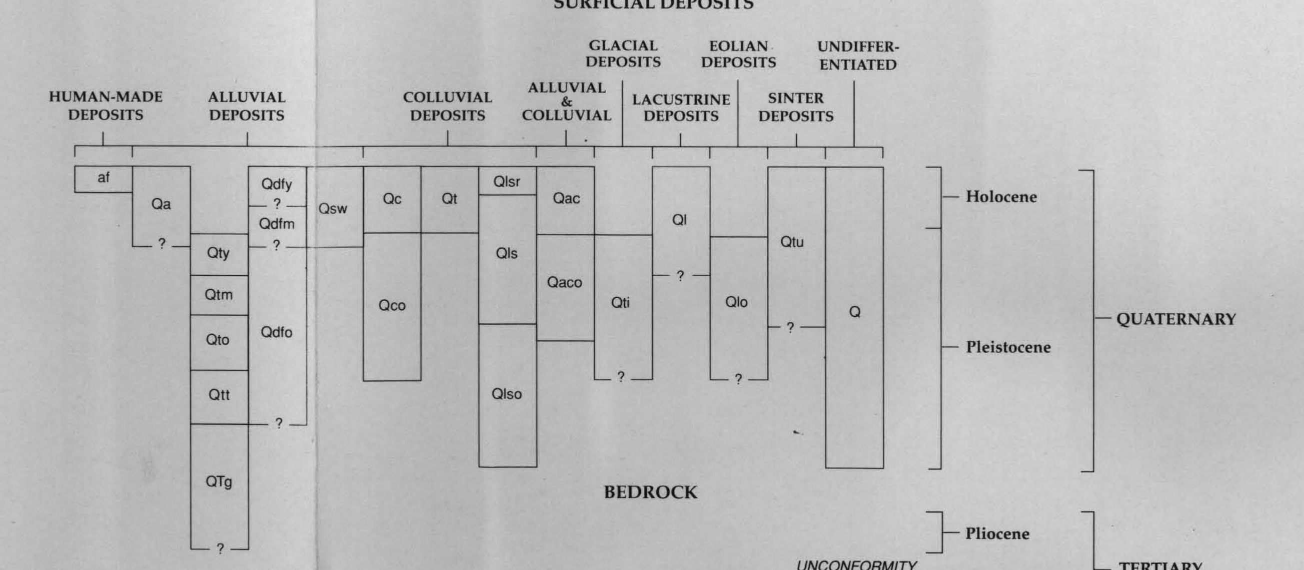
Xg — **Biotite granite (Proterozoic)**—Dark gray and white speckled, fine- to coarse-grained, equigranular granite and granodiorite

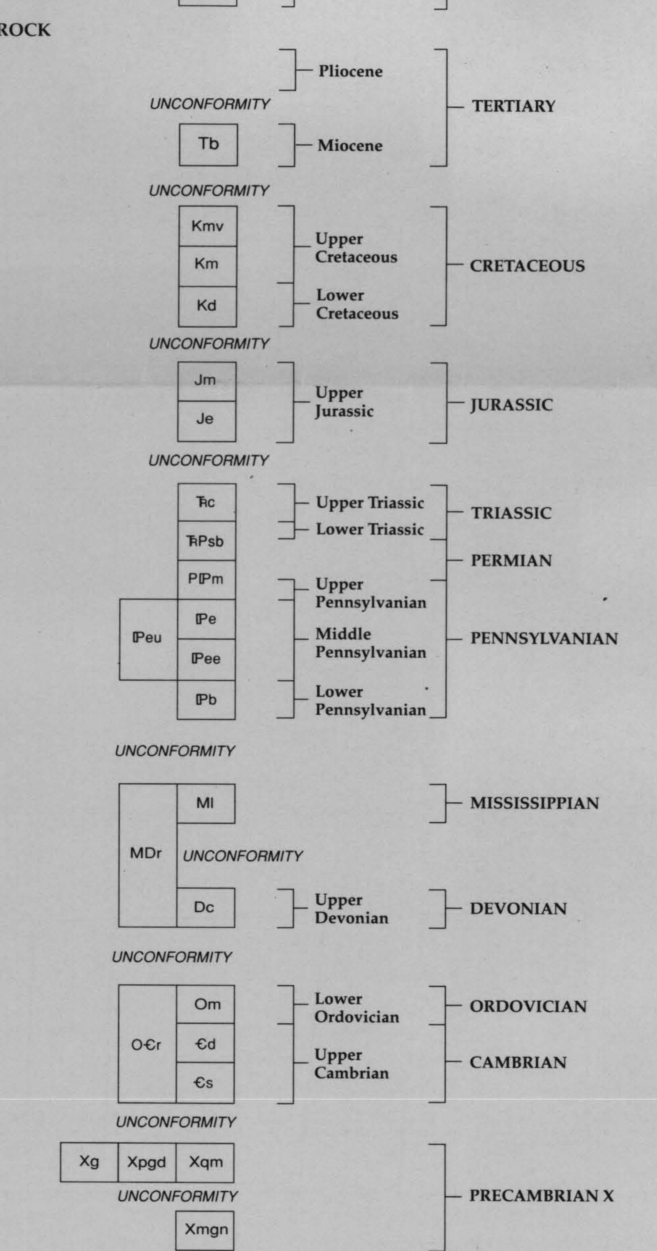
Xpgd — **Porphyroblastic biotite granodiorite of No Name Canyon (Proterozoic)**—Coarse-grained, inequigranular, granodiorite with large, pink euhedral porphyroblasts of orthoclase

Xqm — **Gneissic quartz monzonite of Mitchell Creek (Proterozoic)**—Fine- to medium grained, equigranular, foliated, quartz monzonite

Xmgn — **Biotite-muscovite gneiss (Proterozoic)**—Well to poorly foliated biotite-muscovite gneiss, locally pegmatitic—stipple pattern where mapped

CORRELATION OF MAP UNITS





MAP SYMBOLS

Contact—Dashed where approximately located

Fault—Dashed where approximately located; dotted where concealed; bar and ball on downthrown side

Fold—Showing trace of axial plane, and direction of plunge where known. Dashed where approximately located; dotted where concealed

Anticline—Showing crestline

Syncline—Showing crestline

Monocline—Showing upper and lower fold axes; arrows indicate direction of dip; longer arrow indicates flatter dip

Strike and dip of beds—Angle of dip shown in degrees; most attitudes in basalt were measured on top of flow surfaces

14 **Inclined**

Vertical

Strike and dip of foliations—Angle of dip shown in degrees

7 **Inclined**

Vertical

62 **Axial trace of small antiforms in metamorphic rocks**

37 **Lineation of porphyroblasts**

Moraine crest—Crest of lateral and end moraines

Thermal spring

Quarry or gravel pit

Locality of rock sample—Radiometrically age dated using the $^{40}Ar/^{39}Ar$ method

Sinkhole in surficial deposits

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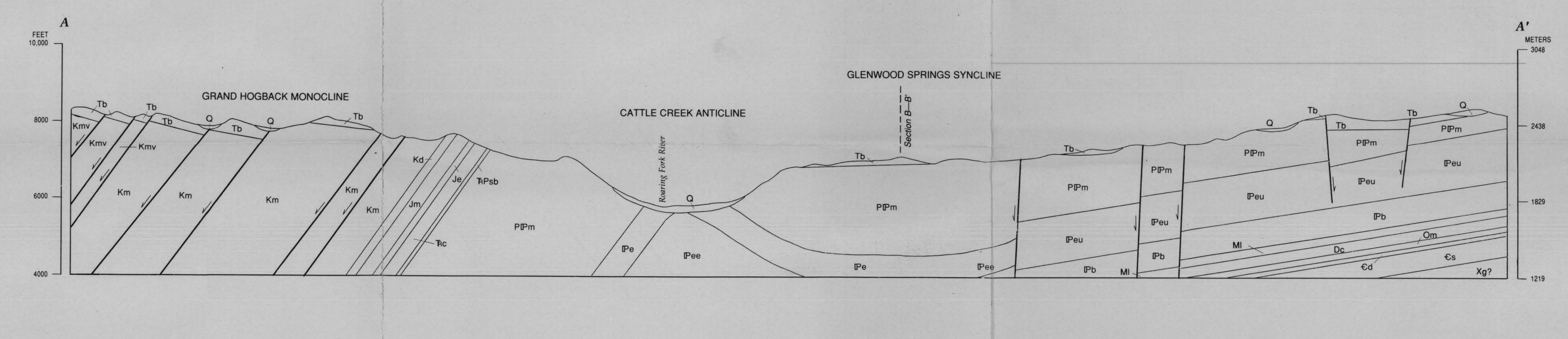

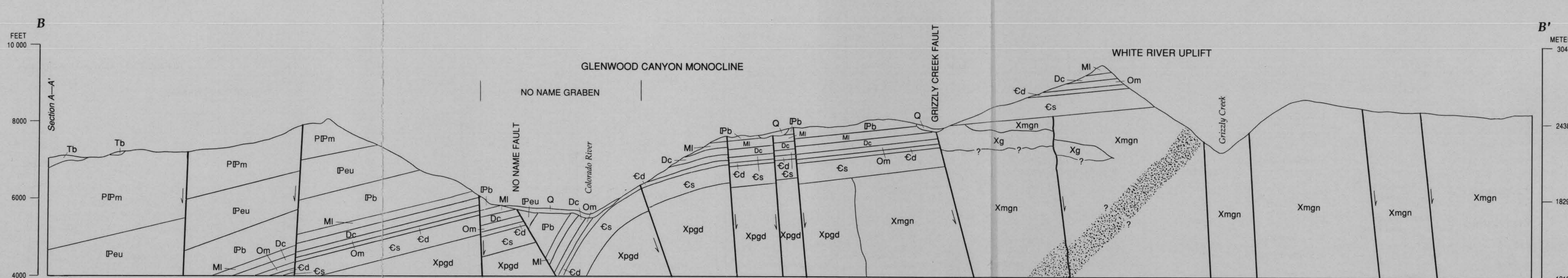

GEOLOGIC MAP OF THE GLENWOOD SPRINGS QUADRANGLE, GARFIELD COUNTY, COLORADO

By
Robert M. Kirkham, Randall K. Streufert, and James A. Cappa

1995